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An Examination of the Outcomes of a Distance-Delivered Science Course[1]

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ABSTRACT

A comparative study was conducted to examine the effects of distance delivery on student performance in a science course. Academic outcomes and interactions were compared among students (n = 44) enrolled in two sections of an upper level Histology course taught over the course of a single semester by the same instructor. Eleven students took the course entirely on-line, while 33 took the course in a traditional, on-campus format. Although the performance of both groups on a content pre-test was indistinguishable, at the end of the study, students in the on-line group significantly outperformed their peers in the on-campus group on a content post-test. The on-line group also demonstrated a greater frequency of interpersonal interactions. Further investigation of the topic and content of interactions revealed that although students in the on-line group initiated a smaller percentage of content-related interactions, these interactions demonstrated higher levels of thought and abstraction than those generated by the on-campus students.

INTRODUCTION

A recent report released by the National Center for Education Statistics (1999), indicates that the number of available distance-education programs rose 72% during the three-year period between 19995 and 1998, with a total of 1,680 institutions offering approximately 54,000 on-line courses to 1.6 million enrolled students. A study by the International Data Corporation (1999) predicts there will be 2.2 million college students enrolled in distance-learning courses by the

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year 2002. These rapid growth trends in distance delivered courses underscore the importance of investigating the impact of this trend on students.

When any type of instructional innovation is being evaluated, the first issue that comes to mind is student achievement of content objectives. Students must demonstrate at least equal achievement (i.e. no significant difference) when learning from the new method as from the currently accepted standard, in order for the innovation to be considered for adoption. There are a plethora of studies documenting both significant and non-significant differences on student achievement (Russell, 1999) when the instructional delivery media is varied. The seemingly contradictory results of this body of literature can best by understood in light of a long-running debate in the educational technology literature. For over 10 years, Clark (1983, 1994a, 1994b) and Kozma (1991, 1994a, 1994b) debated the issue of whether electronic media alone can influence learning. While Clark (1983) felt that "media are mere vehicles that deliver instruction but do not influence student achievement..." (p. 445), Kozma (1994b) argued "both media and methods influence learning and they frequently do it by influencing each other" (p. 11). Based on this debate and a survey of recent literature (e.g. Joy & Garcia, 2000) it can be concluded that media has an indirect effect on learning by facilitating teaching methods which in turn can affect learning. Therefore, the current study compared content outcomes for students in both conditions simply to verify the viability of the innovation (i.e. on-line delivery does not harm students). The impact of the delivery system on student learning was assessed by examining classroom interactions for topic and depth of thought.

The importance of interpersonal interactions in a distance delivered course cannot be understated. Faculty-student interaction is one of the cornerstones of effective teaching, regardless of delivery medium. For example, student-faculty interaction is recognized as one of

the *Seven Principles for Good Practice in Undergraduate Education* because "[F]requent student-faculty contact in and out of classes is the most important factor in student motivation and involvement. Faculty concern helps students get through the rough times and keep on working" (Chickering and Gamson, 1987; p. 4). While this assertion initially targeted traditional instruction, it is just as valid, if not more so, for distance delivered courses. Lack of faculty-student and student-student interactions lead to feelings of alienation, or "being lost in cyberspace" which are commonly cited causes of attrition in distance education (Scott, 1994, Carr, 2000a). In distance education, there are three essential types of interaction, according to Moore and Kearsley (1996). These are: learner-content, learner-learner and learner-instructor interactions. Learner-content interaction refers to how students interface with the course materials. This type of interaction can be affected by the manner in which course materials are designed and presented. Learner-instructor interaction encompasses the exchanges that occur between the faculty member and students in a variety of modes (i.e. course materials, personal communication) and contexts (feedback, encouragement, etc). The functions of this type of interaction range from providing opportunities for the students to practice the concepts they have acquired, to providing feedback on content mastery and also to mentoring students and encouraging them to progress through the course. Learner-learner interactions serve two purposes. First, by discussing content with their peers, students are forced to organize and postulate their understanding of the concepts under study. This explicit communication exposes content misconceptions and allows them to be remedied during the negotiation of meaning that takes place while interacting with peers. A second function of learner-learner interactions is to allow students to form a community and create a support network. According to Souder (1993),

the unique attributes of on-line environments, such as the lack of non-verbal cues, lead students to bond with each other more than they would in traditional settings.

Given the importance of interactions to student success in distance education, this study examined interpersonal (i.e. learner-instructor and learner-learner) interactions in order to see how their topic and depth of thought was affected by the use of an electronic delivery system. Once interactions had been classified by topic, Bloom's classification of questions in the cognitive domain (1956) was used to categorize the level of abstraction of content-related questions asked in the histology course.

RESEARCH QUESTIONS

This study examined the effects of distance delivery on student performance in an upper level science (histology) course.

The specific research questions addressed were:

1. Is there a difference in content achievement between students enrolled in face-to-face (on-campus) and on-line sections of histology (learner-content interaction)?
2. How does on-line delivery affect classroom interactions (learner-learner and learner-instructor interactions)?
    a) Does the delivery medium impact the number of interactions taking place in each setting?
    b) How does the delivery medium affect the quality of interactions in each setting, as measured by Bloom's Taxonomy?
3. How does the presence or absence of an instructor affect the number and type of questions that occur in on-line group interactions?

METHODS

A hybrid approach was used to examine the effects of distance (on-line) delivery on student learning. Observations were conducted in two sections (on-line and on-campus) of the same course, taught by the same instructor over the course of one semester. Since the participating instructor had sole responsibility for the on-line section, but was part of a teaching team for the on-campus course, this study examined student achievement only for the topics she presented in both modalities.

Students enrolled in the on-campus section were observed during regular lecture sessions. Students in the on-line section were observed in two settings – on-line chat sessions, where the instructor was present, and on-line review sessions, which were student-organized review sessions, during which the instructor was not present.

Figure 1: Sample content-test questions

Which of the following statements is false?

1) The basement membrane separates epithelia from connective tissues.
2) The basement membrane is composed of Type II collagen.
3) Parts of the basement membrane are secreted by both epithelia and connective tissue cells.
4) The basement membrane acts as a selectively permeable membrane.

Which of the following statements is FALSE?

1) Adenomeres would be considered part of the parenchyma of a large compound gland.
2) Merocrine glands are found in only a few locations in the skin of domestic animals.
3) The cells lining a secretory duct actually contribute to the secretory product of a gland.
4) Epithelial cells that secrete into the blood stream are referred to as exocrine.

Which of the following sets of terms are LEAST related?

1) Spleen: filters blood
2) Lymph nodes: filter lymph
3) T-lymphocytes: cell-mediated immune system response
4) Thymus: primary lymphatic organ
5) Lymphatic nodules: T-lymphocytes

Which of the following matches of terms is INCORRECT?

1) Epidermis: primarily keratinocytes
2) Dermis: highly innervated
3) Epidermis: avascular
4) Hypodermis: dense irregular connective tissue
5) Dermis: primarily dense irregular connective tissue

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Students in both sections completed the same pre-test, and the instructor presented the same lectures, using the same clinical examples in both situations. Learning outcomes were assessed by student achievement on course exams. The same exam questions were asked of students in both sections, but at different times during the semester. Student scores on the selected questions (Figure 1) were compared by a t-test in order to determine if there were any differences in performance between students enrolled in each of the sections.

The classroom management software used to run the course generated chat transcripts and tracked student performance on both pre- and post-tests. An observer manually recorded data on on-campus interactions. Transcripts of interactions in each setting were independently coded and analyzed by both of the researchers. An interaction was defined as any utterance from a participant in the form of a question. Each question was coded into one of four topic categories:

1. Administrative - questions regarding administrative details of the course, such as due dates for assignments

Examples: "Can you remind us about the 2 ways you would ask a question about secretory glands?" "Are there any labs we can attend to review?" "Approx. how many review questions will there be on the test?"

2. Content - any question directly pertaining to course material

Examples: "Why are erythrocytes anucleate?" "Where are apocrine glands found in animals compared to humans?" "What is icterus and what causes it?"

3. Management - questions used to manage the flow of a class

Examples: "Hi, Bobby! We just started with a quest to describe a cell that looks like it has the potential to divide. Want to give it a try?" "Any of you have hints for Susan?"

"Hey, Don, you've been quiet. Want to ask a question about lectures 1-4 for the group?" "Does anyone want to do a chat the night before the test?"

4. Social - all questions of a non-academic nature.

Examples: "Aren't you glad your names are attached to your answers? No hiding here!" "So what's for dinner? I had left-over spaghetti – not bad." "Did you have a restful spring break? Did you take a break? Read a novel? Lay in the sun? etc?"

Content questions were further classified according to the demonstrated level of abstraction or depth of thought, in accordance with the definitions established in Bloom's Taxonomy (Bloom, 1956):

1. Knowledge: Simple recall or recognition of a concept. E.g. "What are the three layers of the basement membrane?"
2. Comprehension: Interpretation, translation. At this level, the student must be able to demonstrate use of abstraction when asked to. E.g. "Brown fat is found in hibernating and newborn animals. Why is it brown – anybody?"
3. Application: Requires application of an abstraction to new problem without being shown how to do it in new situation. E.g. "Why are the cells lining blood vessels flat and have small, heterochromatic nuclei?
4. Analysis: Breaking down material into constituent parts and detecting relationship of these parts in the whole. E.g. "If you were the Great Creator, now that you've RECOGNIZED the antigen, what do you want to do with it?"
5. Synthesis: Putting together parts and elements to elucidate a previously poorly defined pattern or structure. E.g. "Testosterone stimulates sebaceous glands, so the cure for 'stud tail' in cats is ____?"

6. Evaluation: Judging the extent to which ideas, solutions, methods and materials satisfy criteria. E.g. "What might cause a neutrophilia?"

Data were statistically analyzed via one-way ANOVA and post-hoc comparisons were conducted using the LSD test. An alpha value of 0.05 was selected as the significance level for all tests. A full description of statistical analysis procedures employed can be found in Schoenfeld-Tacher, McConnell & Graham (2001).

Results:

While there were no significant differences in academic performance between students in either section on the pre-test, students in the on-line section significantly outperformed their counterparts in the on-campus section on the post-test. (Table 1).

Table 1: Academic Performance on Content Tests (percentage scores) for Students in Each Course Section

	On-Line			On-campus				
Test	N	M	SD	N	M	SD	df	t
pre-test	6	10.67	9.35	22	15.09	11.51	26	0.863
post-test	11	80.11	10.67	31	72.78	10.15	40	-2.03*

* $p < 0.05$

The average rate of interactions per hour was significantly greater ($F = 6.07$, $p<.01$)for both on-line environments than it was for on-campus lectures. Students initiated a larger percentage of interactions during on-line class sessions than in on-campus sessions (Table 2). This difference was statistically significant ($F = 6.49$, $p<.001$). However, there was no significant

difference in the frequency with which students and instructor initiated interactions within a given setting.

Table 2: Frequency Counts and Total Percentages of Interactions Initiated by Students and Instructor in On-Line Classes vs. On-Campus Lectures

	Instructor		Students	
Section	Number	Percentage	Number	Percentage
On-line	229	59.0%	159	41.0%
On-campus	101	66.4%	51	33.6%

$\chi^2 = 2.54$, $p > 0.05$, no significant difference

The greatest amount of content interactions occurred during on-campus sessions, while the largest percentage of social interactions took place during on-line review sessions (Table 3). There was no significant difference in the percentage of personal interactions initiated by students or instructor in the on-line class sessions. When the combination of initiator and setting was examined, it was found that students were most likely to initiate content interactions in a lecture setting, followed by a chat, followed by a review. The instructor was more likely to initiate a content interaction in a lecture setting than in a chat. In both lecture and chat environments, students were more likely to initiate content interactions than the instructor.

Table 3: Mean Percentage of Interactions per Session Observed in Each Category, by Environment and Type of Initiator

	Environment and Person Initiating the Interaction				
	Student			Instructor	
Topic of Interaction	On-Line Review	On-Line Class	On-Campus Lecture	On-Line Class	On-Campus Lecture
Management	28	20	0	32	18
Social	13	4	0	4	0
Administrative	3	6	2	2	0
Content	56	70	98	62	82

An examination of the level (Bloom's Taxonomy) of content interactions showed that students in the lecture section generated significantly larger percentages of interactions at both the lowest and highest levels than students in the other environments did (Table 4).

Table 4: Mean Percentage of Content Interactions per Session at Each Level, by Environment and Type of Initiator, Using Weighted Data

Question Level and Type	Environment Type and Person Initiating the Interaction				
	Student			Instructor	
	On-Line Review	On-Line Class	On-Campus Lecture	On-Line Class	On-Campus Lecture
Low					
Knowledge	44.2	36.3	52.3	28.3	27.0
Comprehension	33.1	26.0	16.3	34.6	28.6
Medium					
Application	9.6	16.8	15.7	14.4	25.5
Analysis	3.6	10.6	13.7	6.3	15.6
High					
Synthesis	1.2	10.2	0	10.3	3.3
Evaluation	0.6	0	2.0	0.8	0

Approximately 75% of interactions initiated by students in review sessions were low-level (knowledge and comprehension). The percentages of low and medium (application and analysis) questions asked by students in a class setting (on-line or on-campus) were similar to each other, but greater than those for review sessions. The only instance in which students initiated an appreciable percentage of high level (synthesis and evaluation) questions was the on-line chat. The instructor asked a slightly greater percentage of low-level questions in the on-line chat sessions than she did in the on-campus lectures. The differences were more striking for medium and high level questions. The instructor initiated a much greater percentage of medium-

level questions in the on-campus environment and high-level questions in the on-line environment.

CONCLUSIONS

The teaching methodologies facilitated by the on-line delivery system led to enhanced academic outcomes for students in the on-line section relative to those observed for the traditional delivery system (lecture), as measured by performance on a content test. These results support the assertion that it is possible to effectively teach science at a distance, because on-line delivery enhanced learner-content interaction and created improved learning opportunities for students relative to on-campus delivery.

Greater levels of instructor-student interaction were observed in the on-line sessions, clearly dispelling any fears of the delivery medium creating a sense of alienation for students. Although the difference in type of participant initiating the interactions in each setting is not statistically significant, students did generate a greater number of interactions in the on-line sessions, and did so without as much prompting as in the lecture sessions, which reflects their active engagement with the material under study. There were no social interactions observed in the lecture setting, but the instructor was as likely to initiate a personal interaction as the students were during an on-line class. These patterns, along with the sense of 'bonding' reported by the distance students and the instructor illustrate the importance of learner-instructor interactions in promoting learning and how these interactions can be used to encourage student participation. The instructor influenced the level of questions asked during on-line sessions. Her presence shifted the bulk of the questions from the lower levels seen in the review sessions to the more balanced distribution seen in the on-line class sessions.

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Learner-learner interactions are just as important to student success. As expected, students generated more social interactions during review sessions than during on-line class sessions. These interactions enhanced camaraderie and fostered the creation of a community of learners, who provided support for each other during stressful periods. It is interesting to note that all of the students who regularly participated in review sessions successfully completed the course. Interestingly, a greater percentage of management interactions were observed during the review sessions, when the instructor was absent. During these sessions, a student spontaneously assumed the instructor's role and acted as a facilitator/moderator, ensuring that personal interactions were kept to a reasonable level, and that review sessions primarily focused on content.

The overall trend in the distribution of questions among lower and higher levels was comparable for both the on-campus lectures and on-line classes, although the percentage of high-level questions initiated by both students and instructor was greater in the on-line sessions. This demonstrates that on-line delivery led to a shift towards high-level questions in a class-type environment, perhaps because it allowed more time for students and faculty to think about their responses. The use of internet delivery created a more relaxed atmosphere in both of the on-line settings, where students were able to ask questions about a variety of topics.

SIGNIFICANCE OF THE STUDY

While the literature is replete with studies demonstrating no significant difference when two delivery media are compared, (Russell, 1999), this study makes a valuable contribution to the body of knowledge about distance education by considering the effects of a delivery system on classroom interactions.

Although the number of students enrolled in distance delivered courses is rapidly increasing, the impact of distance delivery, particularly on learning in the sciences, is not yet clear. The issue of whether or not it is possible to teach science at a distance without compromising academic rigor has been a topic of recent debate in publications such as the *Chronicle of Higher Education* (Carr, 2000b). This study demonstrates that it is possible to teach a science course (including laboratories) entirely on-line without any adverse effects on academic outcomes.

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